

THE NEW BREED MICRO-HYBRID OPERATIONAL AMPLIFIERS

A STATUS REPORT



PHILBRICK RESEARCHES, INC.

THE NEW BREED MICRO-HYBRID OPERATIONAL AMPLIFIER

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One year ago, in August, 1965, we first introduced our new line of "micro-hybrid" Operational Amplifiers, which were unique in that they combined the best of two technologies — the linear monolithic-chip and discrete micro-miniature components. Since then, a year's evaluation by more than 200 systems organizations has demonstrated beyond question the unequalled performance and reliability of this "NEW BREED".

This summary of what we believe to be the role of the NEWBREED is presented for the information of engineering managers, design supervisors, and senior scientists in the Aerospace/Weaponry field.

It is now apparent that analog-circuit (linear) subsystems relying on monolithic-chip designs are in danger of rapid or even immediate obsolescence; they will be no longer competitive, either technologically or economically.

The micro-hybrid Operational Amplifier, with its absolute immunity to overloads, shorts, and supply-voltage stresses, its order-of-magnitude superiority in many electrical performance parameters, and its far greater convenience in mounting and assembly processing, provides savings in total system cost — in design, development, materials, and labor — that more than compensate for its somewhat higher initial price.

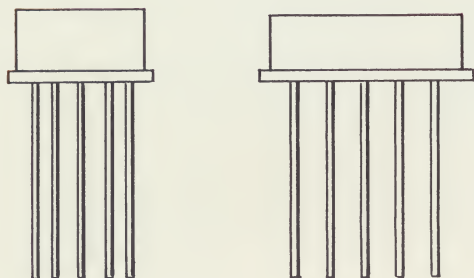
This report has been divided into six "chapters", the titles of which are briefly expanded upon below, in the form of six statements (perhaps "logical propositions" is a better term) that distill the results of this pioneering year of experience . . .

- I. Why we designed the micro-hybrid Operational Amplifier . . . and why those reasons are important to you.
- II. Why Philbrick micro-hybrid Operational Amplifiers are inherently more reliable than any linear-chip design . . . and what this added reliability means to you.
- III. How you can save money on your total system budget, and build a better system, by paying more for the Operational Amplifier.
- IV. How you can help to guarantee the on-time, in-budget delivery of your system, and insure yourself against desperate, drastic redesigns, by basing your design on micro-hybrid Operational Amplifiers.
- V. What the NEW BREED can do for your systems, to make them more competitive, and more attractive to the Aerospace/Weaponry users for whom you design and build them.
- VI. Why micro-hybrid Operational Amplifiers are clearly the components of choice for most systems — even those that don't seem to need them . . . yet.

We believe that, when you read the pages that follow, you will find these propositions fully developed and supported. We shall welcome your entry into the discussion of this important technological advance. Any comment you should choose to make will be welcomed and most carefully considered, you may be sure.

And now to the report . . .

I. Origins of the NEW BREED "Micro-hybrid"



Here are two micro-miniature Operational Amplifiers.

The one on the left is a monolithic-chip design. It is less than five years old, and yet it is already, in many ways, obsolete — technologically superseded by a better kind of design. . . the one at the right.

We call this improved design the NEW BREED. Although their only external distinction is a slight difference in size, the two devices are worlds apart — in performance, in reliability, and in true cost. In all those ways, and in most applications, the newer design is far superior. . . and its superiority has, at this writing, been clearly demonstrated by a year of evaluation, application engineering, and uniformly-successful field service.

The NEW BREED designs are "micro-hybrids"; that is, they achieve their superiority over the monolithic-chip designs by drawing upon and combining the best of each of the two current component technologies: integrated circuitry and discrete-element circuitry. The resultant hybrid has all of the desirable features of integrated circuits, without any of the weaknesses inherent in a totally-committed monolithic-chip construction. It has superior electrical performance; it has far greater functional reliability; and,

although it carries a higher price-tag than the monolithic chip, it is almost always lower in total cost. . . because it costs far less to use, and because its superior characteristics generate significant system savings.

We designed this NEW BREED of micro-hybrids because we are primarily Operational-Amplifier manufacturers. . . the most experienced in the field, by the way. We were far too conscious of the needs of analog systems designers to believe that they would be content to accept for long the deficiencies that were apparent to us in monolithic-chip designs — deficiencies that are inherent in the process, in our opinion, and can probably never be fully overcome, at practical yields and prices.

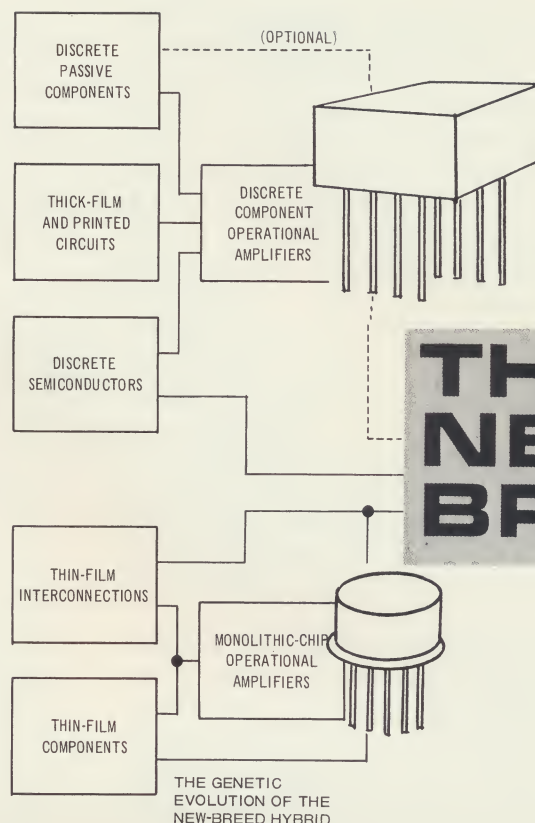
While we believe that the monolithic-chip Operational Amplifier has a role to play in equipment design, we feel that the severe constraints imposed on its design and performance by the single-chip manufacturing process will ultimately restrict it to a narrow range of applications. . . * particularly now that a superior alternative is available, is established, and can be shown to be economically attractive, in most applications.

In this first section, we shall restrict ourselves to a summary of the case for the micro-hybrid, without detailed explanation or explicit proof. In the pages to follow we shall explore each of the elements of this summary in greater depth.

*N. B. Philbrick has designed a number of distinctly-superior monolithic-chip designs, for those applications in which the balance of requirements — economic, functional, and structural — permits the user to take advantage of their lower initial cost and higher output-current capabilities. These designs represent a significant advance in the state of the monolithic Operational Amplifier art, and may present the best compromise between the limited capabilities of older chip designs and the higher performance at higher initial cost offered by the NEW BREED micro-hybrid.

THE NEW BREED —
PHILBRICK'S MICRO-HYBRID
OPERATIONAL AMPLIFIERS
ARE SUPERIOR
TO MONOLITHIC-CHIP
OPERATIONAL AMPLIFIERS
BECAUSE. . .

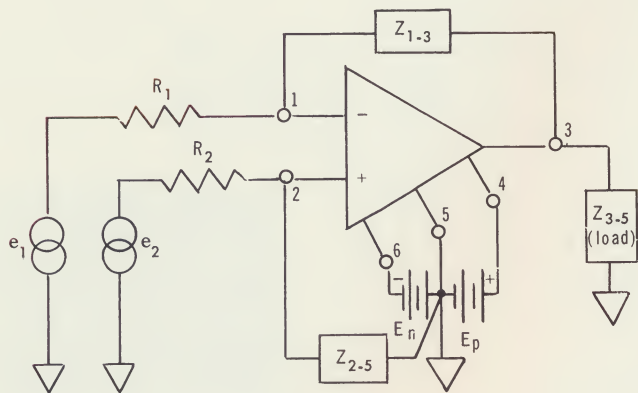
- 1 They are almost completely immune to all forms and combinations of external circuit or signal stress — to a degree that has not even been approached in a monolithic design.
- 2 Their electrical performance over the entire rated operating range (of environmental and signal/supply/load parameters) provides a generous margin of functional reliability in every class of circuit applications — a margin that has not even been approached in a monolithic design.
- 3 Their performance need not be restricted to a particular and narrow range of parametric trade-offs, but may be adjusted (if necessary) to the needs of the system — a recourse that is economically and technologically impractical in the monolithic-chip manufacturing process.
- 4 They are easy to install, inexpensive to package, practical to inspect, test, and even replace. In contrast, monolithics often cost many times their "delivered price" to convert into a final, working system, and involve difficult tool-design and assembly techniques, because their TO-5 or "flat-pac" cases have 0.076" spacing, which requires multilayer boards for reliable interconnection.
- 5 They can provide higher output voltage and power than monolithics, despite their superior immunity to shorts, overloads, overvoltage, excessive drive, etc., etc.
- 6 They can do many jobs that are impossible, at any price, for any monolithic-chip amplifier.



- 7 They free the designer from the need for complex and expensive external circuit "fixes", whether for protection, stabilization, or compensation. Monolithic-chip designs, on the other hand, demand just such added effort and expense.
- 8 They can (and will) grow with the semiconductor technology, far more than linear-chip designs, because only a few kinds and combinations of semiconductors may be incorporated in monolithic devices. Therefore, many new developments in the art will expand the horizon of the NEW BREED, but rarely will such advances benefit the monolithic-chip device.

There you have our reasons for preferring the NEW BREED to the old. When we have amplified them, and offered proof, it should be obvious that they ought to be your reasons, too.

II. Superior Reliability of the "Micro-hybrid"



This is a typical application for a differential-input Operational Amplifier — of any construction, by the way: monolithic, discrete-element, or the NEW BREED micro-hybrid. Let us consider, briefly, the stresses that may be imposed on the amplifier by the external circuit, and on the external circuit by the amplifier's reaction to those stresses.

Let us also consider other sources of stress, and other consequences of strain — i.e., environmental effects, as well as circuit effects. Finally, let us not omit from our consideration all significant and likely combinations of environmental and circuit stresses, and their consequences.

When we have completed our analysis, it will be apparent that monolithic Operational Amplifiers are so consistently vulnerable, to even the most common of stresses encountered in complex aerospace/weaponry systems, that their use should always be avoided in any program having high functional reliability as one of its goals.

All NEW BREED amplifiers, on the other hand, have been designed for complete immunity to every stress considered herein. . . and what is more, their behavior under stress is conservative, and not likely to damage external circuits.

This superior resistance to stress is attributable entirely to the design freedom that has been preserved in micro-hybrids (and sacrificed in monolithic designs) — namely, the ability to select semiconductor types, circuit configurations, and parameter values that will ensure conservative, self-protecting behavior in the amplifier. The number of discrete components used in a micro-hybrid need not be great in order to achieve this resistance to stress and other superiorities. . . but the external effect of adding those few is overwhelming.

The table that follows will help to organize our analysis of the behavior under stress of both types.

The table at the right will help to organize our analysis of the behavior under stress of both types. It does not include combinations of stresses, amongst the most common of which are:

- "Launch" stress patterns, such as supply-voltage surges combined with momentary shorts and overloads.
- "Pre-stabilization" stress patterns, such as very high thermal gradients combined with overloads and excessive signal levels.
- "Slewing" stress patterns, such as excessive signals combined with capacitive-charging overloads.
- "Reset" stress patterns, such as capacitive-charging overloads (and excessive signals) combined with high thermal gradients.

Is there a way out? Is there some way to use the lower-priced linear-chip amplifiers, despite their vulnerability, and still achieve reasonable system reliability? Sometimes there is — but the cost may be higher than you care to pay, in dollars, in cubic inches, in watts, in pounds. . . and in complexity, which means design time and effort, as well as lower MTBF.

For example, it is possible to design a power-supply regulator that will absorb a severe power-line surge, but it will be far more expensive, have far higher dissipation, be larger, heavier, and less reliable . . . can you afford it?

TABLE I
COMPARATIVE BEHAVIOR
UNDER STRESS

CLASS OF STRESS	PARTICULAR TYPE OF STRESS	BEHAVIOR UNDER STRESS	
		BEST AVAILABLE MONOLITHIC DEVICE	PHILBRICK NEW BREED
SUPPLY VOLTAGE SURGES	Line-induced over-voltage due to regulator recovery characteristics of as much as 180% (280% of nominal) for transient intervals of 0.1-2 sec.	Usually fails by breaking down output junctions	No Effect
	Power-supply regulator failure, averaging 80% overvoltage (180% of nominal) for indefinite (long) periods	Most units fail, some within 1 second	No Effect
MOMENTARY SHORTS AND OVERLOADS	Output to Ground (Term. 3-5)* prolonged short (>1 sec)	Some units fail after 5-10 sec. Few can short indefinitely	No Effect
	Output to Supply (Term. 3-5)* prolonged short (>1 sec)	All units fail after 2-5 sec. and draw fault currents of 10-500 times normal, thereafter	No Effect
	Input to Supply (Term. 1 or 2 to 4 or 6)* prolonged short (>1 sec)	All units fail within 10 sec. and some draw fault currents of 5 to 100 times normal	No Effect
	Positive Input to Output (Term 2 to 3)* prolonged short (>1 sec)	Some units fail after 5-10 sec. Most are permanently damaged	No Effect
ENVIRONMENTAL EXTREMES AND SURGES	Violent acceleration and Vibration	No Effect (except for failures induced by short circuits in external equipment)	No Effect
	Rapid changes in temperature (100°C/minute) altitude, and humidity (per MIL specs)	No Effect	No Effect
EXCESSIVE SIGNAL CONDITIONS †	e_1 or $e_2 = 90\%$ of E_p or E_n , and R_1 or $R_2 < 100\Omega$, prolonged (>1 sec)	Most units fail after 5-10 sec. All units draw excessive current from e_1 or e_2 , and from power supplies.	No Effect
	e_1 or $e_2 = 50\%$ of E_p or E_n , and both R_1 and $R_2 \rightarrow 0$, prolonged (>1 sec)	A few units fail after 20-50 sec. All units draw excessive current from e_1 or e_2 , and from power supply.	No Effect

*Terminal Numbers refer to diagram on Page 4

†Parameter Nomenclature refers to diagram on Page 4

Again, it is possible to externally "pad" the terminals of the amplifier with series resistance to prevent it from drawing high currents when short-circuited or momentarily over-driven or over-loaded; but then you have altered the properties of the amplifier (sometimes unpredictably, from unit to unit) and it may not be reliably stable, or fast, or capable of wide dynamic range — and are you prepared to spend weeks or even months to investigate such a "patch". . . and can you justify it technically with confidence?

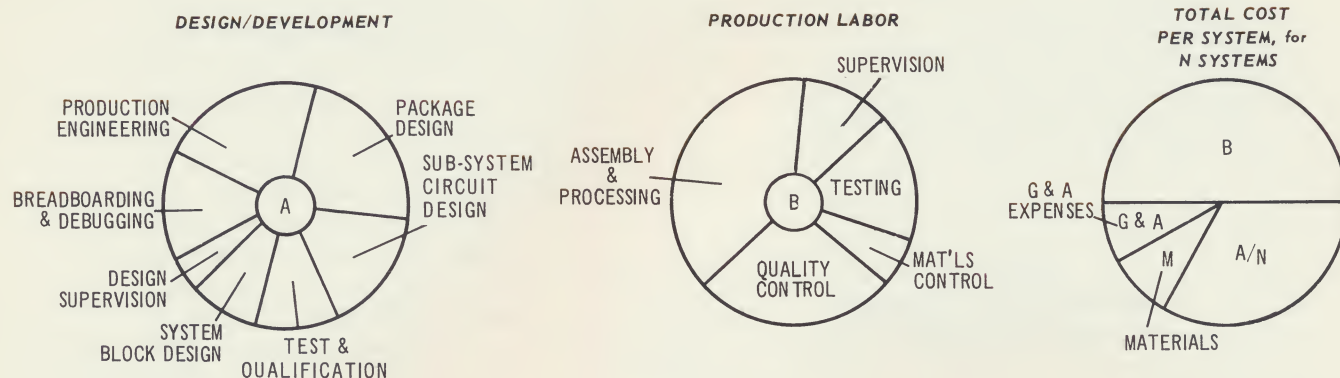
It is impossible, in this brief monograph to cover every combination of stress, strain, and corresponding external circuit relief. We shall simply leave you with this thought:

In most instances, a critical-system reliability analysis will show that the compromises and expedients required to raise the immunity of a monolithic-chip Operational Amplifier to acceptable levels are not justifiable, when contrasted with the micro-hybrid alternative.

III. True and False System Economy

The charts that follow are typical of many airborne, spaceborne, submarine, or mobile systems. All such systems are characterized by five constraints:

- Size, weight, and power consumption (efficiency) are all at a premium.
- Short-term (single-mission) reliability must allow for very severe stresses, including post-checkout "launch" conditions.
- Production volume is relatively low, so that design, development, and system-packaging costs are a high percentage of the cost per system.
- The cost of design revision and production rework is much higher than in commercial development, because even minor changes must be revalidated.



- Production labor is a much higher percentage of manufacturing cost, and materials and components are a much lower percentage of total manufacturing cost, than in most other kinds of non-consumer electronics. Most of this difference is caused by the elaborate QC routines and the special manufacturing processes required for QA.

System Managers are well aware of the implications of these constraints, for the economics of survival and success depend upon intelligent — often inspired — manipulation of factors A and B with respect to the cost of materials (M) and the G&A expenses.

Individual design engineers tend to lose sight of the big picture, however, and they can, in their enthusiasm, form judgments that lead to significant loss of time and profit. This is especially true with regard to their selection of components and circuits. Among the most common of these faulty decisions are:

- 1 "Saving" 50% of the materials cost. . . at the expense of 20% additional design time and 20% additional production labor. (Compare B & A/N with M in the preceding chart. Note that 50% of M is much smaller than 20% of (B + A/N).)
- 2 "Saving" money on a component in their subsystem block. . . by creating the need to spend far more money in someone else's block. (For example,

by selecting components that are low in cost, but that require a much more expensive power supply.)

- 3 Ignoring the packaging-cost or production-cost differences between two components. (One example of this kind of poor judgement is selecting a "low-cost" micro-module in a TO-5 can or "flat-pack" (which require a multiple-layer circuit board) because it appears to be cheaper than a micromodule in a TO-8 can. . . which requires only a two-sided (at most) p.c. board, and is therefore significantly cheaper to mount, and has far lower mechanical design cost.)

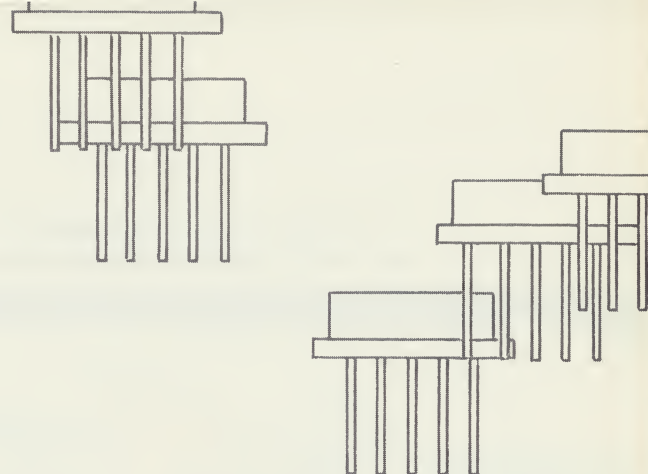
In most of the systems under discussion the analog circuitry represents one of the smallest parts of the bill of materials — but one of the largest parts of the Engineering and QC-QA budget. It is usually the most critical and stress-sensitive part of the system. Therefore, the analog components should be selected for the widest operating margins possible, for the greatest obtainable immunity to stress, and for the most trouble-free breadboard-to-package conversion.

In other words, the place to save money in designing analog circuitry for most systems is not on the components, but on the design, breadboarding, packaging, production. and debugging!

TABLE II
COST COMPARISON OF
ANALOG SYSTEMS ⁽¹⁾ USING
TWO DIFFERENT KINDS OF
MICRO-MINIATURE OPERATIONAL AMPLIFIERS

Cost Element	Using Conventional Monolithic- chip Amplifiers	Using Philbrick "New Breed" Amplifiers
SYSTEM (Block) DESIGN	\$ 1,800	\$ 1,800
SUB-SYSTEM (CIRCUIT) DESIGN	5,000 (2)	3,200
BREADBOARDING AND DEBUGGING	3,300 (3)	2,000
PACKAGE DESIGN	5,200 (4)	3,600
PRODUCTION ENGINEERING	5,500 (5)	3,500
TEST AND QUALIFICATION	1,800	1,800
DESIGN SUPERVISION	2,260 (6)	1,600 (6)
TOTAL "A"	\$24,860	\$17,500
A/N (for 25 Systems)	\$994	\$700
ASSEMBLY AND PROCESSING	\$445 (7)	\$305
MATERIALS CONTROL	80 (8)	65 (8)
TESTING	125	125
QUALITY CONTROL	275	195
TOTAL "B"	\$925	\$690
MATERIALS		
4 Amplifiers	\$176	\$592
2 Circuit Boards	46	16
Other Components	245 (9)	209
Allowance for "Shrinkage" in Production	145 (10)	—
B + A/N (from above)	\$1,919	\$1,390
G & A (8.2%)	208	181
TOTAL COST/SYSTEM	\$2,739	\$2,388
TOTAL COST (25 SYSTEMS)	\$68,475	\$59,700

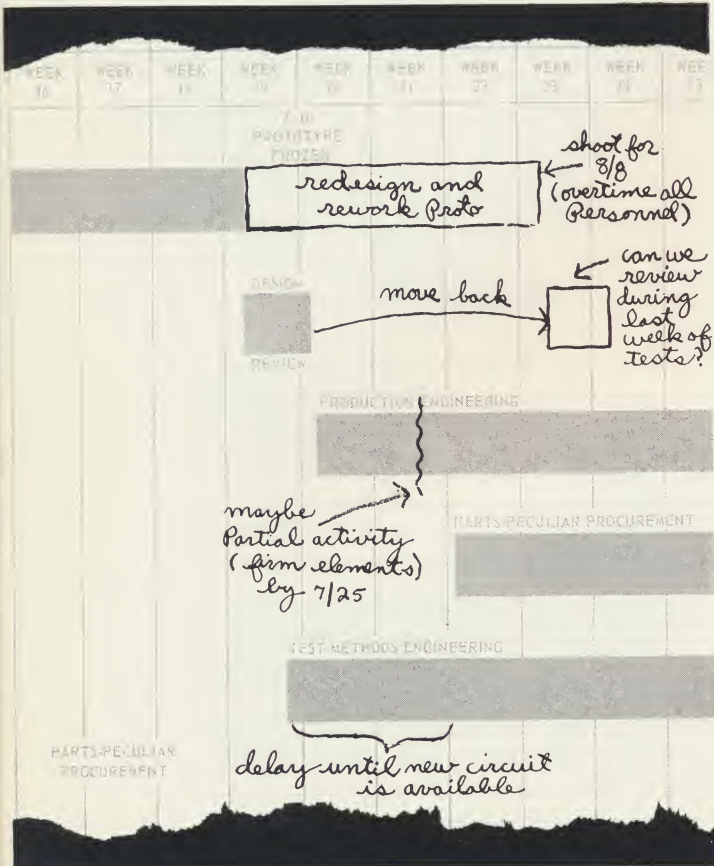
The table above is a perfect example of what we mean. It shows the disastrous effect of using a monolithic-chip Operational Amplifier, instead of a Philbrick micro-hybrid, in a practical system. Note that the 3.5 to 1 price ratio of the two amplifiers is more than neutralized by "hidden" costs in design and production. In fact, the "saving" in the amplifiers is offset by an over-all loss of almost 15% in the total system price!



NOTES FOR TABLE

1. We have used as our basis for comparison a hypothetical (but recognizably typical) case in which a total of four Operational-Amplifier circuits — a subtractor, a summer, and two integrators — are to be mounted on two boards, as a small part of a larger system. 25 such systems are to be produced, under rigid quality control.
2. Allows for design of extra protective circuitry, and means for compensating for low input impedance (and poor CMRR at high impedance) of monolithic designs. . . also, extra power supply design effort, due to lower immunity from power supply variations in monolithic design.
3. Allows for higher cost of multi-layer bread-board setup, more-frequent failure due to fragility of monolithic device — hence more rebuilding. . . also, more time required to achieve and verify dynamic and thermal stabilization.
4. Allows for generating multi-layer board design and procurement specifications. . . also for greater number of components (see note 2).
5. Allows for higher cost of designing processes and tools for handling and connecting TO-5 or flat-pack chips, on multi-layer boards, and for higher component density (see note 2).
6. Calculated as 10% of all design costs above it.
7. Allows for multi-layer board use (see note 5) and for assembly of extra components (see note 2).
8. Approximately proportional to number of components.
9. Allows for extra components for protection, etc. (see note 2).
10. Allows for high reject rates of assembled boards, which are not repairable. (Industry experience indicates 25-35% reject rate.)

IV. INDUSTRIAL LIFE INSURANCE (Deadlines, Dead Ends, and Dead Issues)



This fragment of a design-project schedule chart illustrates a typical case of project failure in aerospace/weaponry system design and production. . .

- . . . failure to run at a reasonable profit
- . . . failure to meet a reasonable delivery schedule
- . . . failure to stay within a reasonable budget
- . . . failure to conform to a reasonable performance specification.

Why does this happen, and how can it be prevented?

Although there might appear to be many reasons for a systems project to go sour, there are really only three important ones:

1. Unrealistic estimates of creative abilities, manpower, or available support.
2. Failure to identify defective design decisions in time to neutralize their potential damage.

3. Premature commitment of key system elements to untried electrical and mechanical designs, without adequate "escape routes".

The first source of trouble is a matter of management maturity and related experience. All one can say is, "Be Realistic, Guess Right, and Good Luck!"

The second source has been discussed in Section III. Part of the solution lies in frequent, prompt, effective review of every phase of every project by personnel who are competent to evaluate the potential danger in the design decisions they are offered. The rest of the solution lies in careful briefing and planning at the time of assignment, and at significant milestones along the way.

The third source of eventual project failure can best be neutralized by obeying the injunction to "Stay Loose!" In other words, never take a chance unless you see a way out, and know when to use it

— which brings us to one of the most important advantages of the micro-hybrid device in general, and to the Philbrick NEW BREED of Operational Amplifiers, in particular.

To begin with, even the lowest-priced of the NEW BREED is a much better amplifier than any monolithic-chip design you can buy, regardless of the price. If you base your design on that amplifier, you are ahead right from the start. Operating margins are generous, ratings are ultra-conservative, and we have probably anticipated in our design a great many of the "surprises" that monolithic-chip designs haven't provided for. . . because they can't.

If you put the NEWBREED amplifier into the earliest breadboards and prototypes, you will find that it's a typical Philbrick product — docile, "forgiving", and eminently rational in its behavior. It is easy to stabilize, dynamically and statically. The specifications have been written to

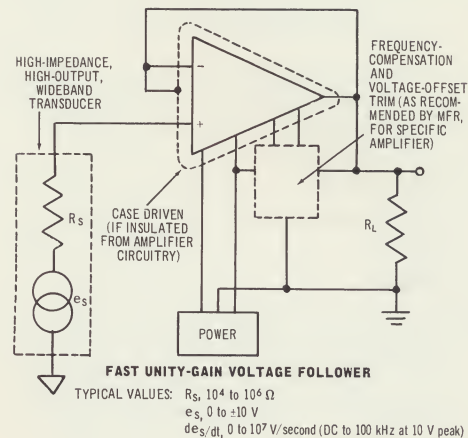
enhance your chances of immediate success. For example, input current is given "raw" ("bias" current) — not as the more attractive, but often dangerously misleading, "tracking" ("offset") value, which is only a part of the input current for which one cannot compensate in many applications.

But suppose that, in spite of all of these margins for error, your design falls short of the required performance goals. Are you sunk? Is it a question of "back to the old drawing board"? Not at all. We have several more rabbits left in the hat. For one thing, you may be able to "move up" a notch in the Philbrick micro-hybrid family.

If none of the standard designs in the NEW BREED family will bail you out, we may be able to provide a modified version of one of them that will. The reason we may is inherent in the hybrid philosophy; every critical component involved in the design trade-off procedure has been made a discrete component, and not committed to the expensive tooling associated with the thin-film chip. Most impressive of all — we may be able to deliver prototype custom units in a matter of weeks, and "selected-better" specials in a matter of days in emergencies! When you go into production, you will find that the cost of a custom design is pleasantly close to the cost of the standard unit. . . and far below the cost of a major system redesign.

In contrast, if you commit your designs to a monolithic-chip amplifier, you had better be right the first time. . . because there is very little that the "monolithic-only" manufacturer can do for you if his standard unit won't work. In fact, about the only thing he can do to help you, economically and quickly, (short of lending you a revolver) is to recommend a Philbrick NEW BREED Amplifier!

V. RELATIVE MERITS, AND ABSOLUTE CAPABILITIES



As the table on the next page shows, the Philbrick Q25AH and Q85AH micro-hybrids outperform the best available monolithic-chip device to a very significant degree, in many important ways. The performance of the circuit shown in the schematic, when a NEW BREED amplifier is used instead of a monolithic chip, is so much better that the entire system in which it appears can be rated at about an order of magnitude better in accuracy, stability, and repeatability!

You may never use the circuit shown above in one of your systems* — but it has important implications for you, just the same.

It shows how a higher-performance micro-circuit Operational Amplifier — the Philbrick NEW BREED, for example — can allow you to offer better system performance and higher system reliability, than can be offered by any design organization that still relies on the old breed. . . the monolithic-chip Operational Amplifier.

*It happens to be typical of the signal-conditioning required for airborne and spaceborne acoustic transducers.

What is more, if you don't need the inherent advantage functionally, you may use it in other ways:

- To take the "performance pressure" off associated circuits, so as to cut cost and increase reliability.
- To widen the operating margins, so as to cut the size, weight, cost, and power dissipation of the power supply.
- To permit the use of simpler, more reliable, less sensitive transducers. . . possibly at lower cost, size, and weight.
- To reduce or eliminate the need for grounding planes, shielding, guarding, multi-layer circuit boards, and heat sinking. . . thus removing many ex-

pensive packaging and production constraints — at great savings in time, effort, and expense.

- To simplify test procedures, and even to eliminate many of them — not only in the production and QC/QA of this circuit, but in the associated system elements that form its interface.

Many of the improvements suggested in the above list are implicit in the excellent common-mode characteristics of the NEW BREED, which provide far greater CMRR, over larger input-voltage ranges than does the chip, and ensure meaningful preservation of these characteristics, despite unbalance in the source resistances, by presenting much higher input resistances to the sources.

This combination of parametric superiorities has other useful application advantages. For example, the Supply-Voltage Rejection Ratio is so much better than in the best monolithic-chip design that far less power-supply regulation is required for a given stability and accuracy. Hum and noise limits in the power supply may also be relaxed. Larger amounts of common-mode ground-loop noise and hum may be tolerated, too.

What does not show in our schematic, but is vitally important — both as a system-performance and an economy factor — is the markedly superior stress resistance of the NEW BREED designs. The reason that this factor does not show is that the NEW BREED does not require external-circuit support or protection. If our schematic were drawn for a monolithic-chip amplifier, it would have to show a considerable array of diodes, zeners, and resistors, added to prevent damage due to signal and supply-voltage transients, and from momentary overloads.

Ask yourself this:

If you were a NASA or DOD engineer evaluating a system based on several of the circuits we have just discussed, which Operational Amplifiers would you bet

TABLE III —
COMPARATIVE
SPECIFICATIONS

(at 25°C, or over the range -25°C to +85°C)

	Q25AH	Q85AH	Best Monolithic
Initial Voltage Offset, max.	10 mV	6 mV	6 mV
Voltage Offset vs. Temp., typ.	15 μ V/°C	5 μ V/°C	6 μ V/°C
Voltage Offset vs. Temp., max.	55 μ V/°C	27 μ V/°C	11 μ V/°C
Initial Input Current, max.	0.15 nA	220 nA	500 nA
Input Current Tracking, max.	0.05 nA	50 nA	200 nA
Input Current vs. Temp., max.	0.1 nA/°C	4 nA/°C	9 nA/°C
Voltage gain, DC, Rated Load, min.	20 k	20 k	25 k
Common Mode Voltage Range, min.	10 V	11 V	8 V
CMRR, min.	5 k	20 k	3 k
Input Impedance, C.M., min.	10 ¹² Ω	500 M Ω	not specified
Input Impedance Diff., min.	10 ¹⁰ Ω	2 M Ω	150 k Ω
Common Mode Voltage, Absolute max.	± 15 V	± 15 V	± 10 V
Differential Input Voltage, Absolute max.	± 20 V	± 10 V	± 5 V
Output Short-Circuit Protection:			
to Ground	Long term	Long term	5 sec max
to ± 15 V Supplies	Long term	Long term	none

TABLE IV —
COMPARATIVE PERFORMANCE IN
FAST UNITY-GAIN VOLTAGE
FOLLOWER CIRCUIT

(Voltage Offset adjusted to Zero at 25°C)

	Q25AH	Q85AH	*Best Monolithic
Maximum swing, DC and LF	± 10 V	± 11 V	± 8 V
Max. Freq. for Full Swing	100 kHz (min.)	100 kHz (min.)	4 kHz (typ.)
Max. DC Common-mode & Gain Error, $R_S = 10$ k Ω , $R_L = 5$ k Ω	.025%	.01%	.03%
Max. Source Resistance for 0.1% DC Error	67 M Ω	45 k Ω	20 k Ω
Input Capacitance	5 pF	3 pF	4 pF †
Noise Figure, $R_S = 10$ k Ω , 20 Hz to 20 k Hz	4 dB	3 dB	10-12 dB †
Case usable as a Driven Guard	yes	yes	no
Small-Signal Transient-Response Time Constant	0.1 μ sec	0.1 μ sec	0.3 μ sec
Temperature $R_S = 10$ k Ω drift (-25°C to +85°C)	0.06% 10 ⁻⁴ Ω	0.07%	0.11%
	0.16% 10 ⁻⁶ Ω	4.40%	9.5%

*Data is taken from published specifications for the highest-performance monolithic unit available as of 6/1/66.

† Input Capacitance and Noise Figure are not specified by the manufacturer of the best available monolithic chip device. These figures were obtained by actual measurement of enough samples to obtain consistent results.

would give the best-performing system, the most economical system, and the most reliable system?

The NEW BREED. . . of course. That's why we've poured so much into its development, and why it is the microcircuit Operational Amplifier of choice, for every new high-performance Aerospace/Military system.

VI. WHY THE MICRO-HYBRID MUST SUPERSEDE THE MONOLITHIC

Let's go back five or six years, to the days when monolithic-chip microcircuits were first proposed for digital devices. If you had ignored them, or their potential, would you be in a position today to bid on digital aerospace/weaponry systems? Not on your life.

Digital monolithic microcircuit modules have swept into ascendancy because they have realized the great potential they displayed five years ago. Analog (or "linear") micro-circuits have been around just as long, but they've never really captured the linear-device market.

Why? Because they never displayed, and do not, in fact, have the inherent technological potential that was so evident in their digital counterparts. The reasons for this are complex, and rooted in the physical limitations of the monolithic-device art, but we shall attempt to describe them briefly.

Before we launch into the reasons, however, let us complete our historical analogy. In our considered opinion, the micro-hybrid Operational Amplifier — Philbrick's NEW BREED — displays the same clear-cut potential for technological dominance in the analog portions of the Aerospace/Weaponry systems of the future as did the digital monolithic device in 1960. Therefore, we believe that it behooves every system designer to consider this potential, and to ensure that the systems he designs today will have longevity, follow-on, and future compatibility, by evaluating, and probably adopting, at once, the linear micro-hybrid. . . even if he can still

"get away with" the use of linear-chip devices in some systems.

Now to return to the reasons why we believe that the linear monolithic device is slated for ultimate obsolescence, now that the micro-hybrid is available:

1 The very processes and physical phenomena that must be used to achieve practical control of tolerance and economical yields in monolithic-device manufacturing today, impose rigid upper limits on the V_{CE0} of the semiconductor elements formed in them. As circuit operating levels approach these limits, the junction noise escalates rapidly, the temperature tolerance narrows, and the junction activity (current and voltage offsets) runs amok. Unfortunately, analog circuits must have a high ratio of dynamic output swing to noise and offset activity at the junction, if they are to be accurate and useful.

2 Most monolithic constructions cannot create usable, well-controlled, high-yield PNP junctions, and the NPN junctions they do create easily (at high yield) have low beta, and — as noted above — low V_{CE0} . Despite the highly-creative efforts of several very competent specialists, over the years, this very narrow choice of uniformly-inferior semiconductors always forces upon the monolithic designs some undesirable combination of the following:

- (a) poor rejection of power-supply variations
- (b) poor CMRR
- (c) slow dynamic response
- (d) dynamic instability
- (e) narrow output voltage range
- (f) small CM voltage range
- (g) vulnerability to external stress
- (h) narrow small-signal bandwidth
- (i) poor voltage offset and drift
- (j) poor input current and drift
- (k) common-mode input resistance

3 The geometry of monolithic chips almost completely precludes guarding, shielding, or significant high-frequency isolation of sensitive circuits; and the need to control parametric tolerances for high yield places a fundamental limitation on the maximum resistance

that may be used in them. This unfortunate combination of circumstances makes it even harder for the monolithic-chip circuit designer to compensate for the low-grade semiconductors he is forced to use. The results are: low input impedance, poor control of bandwidth, and extremely tricky and conditional dynamic-stabilization properties.

- 4 The junctions in a monolithic chip are tiny; therefore, the inherent voltage/current/power restrictions in monolithic devices are most oppressive, and this limitation leaves no room for wide safety margins, as you might well imagine.

We are reminded, when we review the problems faced by the linear-chip designer, of Samuel Johnson's comment "It is, Sir, much like a dog walking on its hind legs; we wonder not at how well it is done, but that it is done at all!"

In the micro-hybrid, on the other hand, the designer need not accept any of the limitations we have just described. He may select PNP or NPN junctions, or even FET's. He may select semiconductors with any conventional V_{ce} rating. He may select beta ranges, offsets, or noise figures. He may even, if necessary, use a discrete resistor of high value here or there. He need not hesitate to ask a junction to dissipate a few extra milliwatts — there is almost always another semiconductor to choose, if the first one won't handle the power conservatively.

Most important of all, if the designer of a micro-hybrid Operational Amplifier is faced with the need to create a custom variation (or even a substantial redesign) he can usually accomplish the change, and be in production, in a matter of weeks — sometimes days! Unless a gross fundamental behavior change is required, he can usually do this by substituting different discrete components for the ones used in an established design — without tooling or processing costs of any significance. The quantity of special units need not be astronomical, either. Think of the added security this gives you, as a system designer, knowing that you need not feel that it is "this chip or

nothing". . . knowing, in fact, that you can often "bail out" of trouble, quickly and inexpensively, by using a custom variation of a micro-hybrid, if the standard you tried to use won't quite do.

Isn't it clear that the micro-hybrid has the clear-cut advantage. . . now and in the foreseeable future? It is clear to us, and has been for several years. Isn't it equally clear, considering all six of these monographs, that you ought to be evaluating one or more of Philbrick's NEW BREED — right now? We hope so. There's a list below, and a 'phone number on the back cover — combine them, and you can start testing inside 48 hours!

THE PHILBRICK
NEW BREED
Report as of August, 1966

Q25AH (FET-INPUT DIFFERENTIAL, LOW CURRENT-OFFSET, HIGH INPUT IMPEDANCE) — Introduced August, 1965, after extensive and prolonged laboratory and production-line studies. At this writing, evaluation units are in more than 150 programs, have been put on a production basis in 15 of them, are still in prototype evaluation in 41 more. Remainder are still in evaluation stage. Rejections — zero. Characteristics in brief: 0.1 nA/°C input-current T.C.; 15 μ V/°C voltage-offset T.C.; $10^{12}\Omega$ input impedance, C.M.; CMRR of 5 K min.; common-mode voltage ± 15 V max.

Q85AH (HIGH-CMRR DIFFERENTIAL, LOW VOLTAGE-OFFSET, HIGH INPUT IMPEDANCE) — Introduced August, 1965, after same study program as Q25AH. At this writing, evaluation units are in more than 100 programs, are on a production basis in 11 of them, are still in prototype stage in 28. Remainder are still in evaluation. Rejections — one (replaced and accepted for prototype design). Characteristics in brief: 5 μ V/°C voltage offset T.C.; 4 nA/°C input-current T.C.; 500 M Ω input impedance, C.M.; CMRR of 20K min.; common mode voltage, ± 15 V max.

Q66A Current Booster with High Slewing Rate — Now in final trials, it will be introduced in the last quarter of 1966. Designed for current amplification inside the loop, Q66A will extend the usefulness of the NEW BREED to such power applications as driving servos and similar electromagnetic/electromechanical loads.

ON THE DRAWING BOARD — Built-in Phase Compensation for NEW BREED amplifiers like the Q85AH and Q25AH, holding out the promise of unconditionally stable micro-hybrid amplifiers. Their introduction will make microminiature devices available to those circuit designers who do not have the time or patience (or room on their circuit boards) to use external compensation.

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